

Reactive Species Transfer and Generation in Plasma-Liquid Systems

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Abstract: Processes in plasma-liquid interaction are fundamental for applications in health, environment and chemical processing. It is vital to investigate the physico-chemical processes of plasma-liquid systems. The interaction at the interface often eludes a detailed diagnostic. This work shows ways to study the fundamental plasma-liquid processes by combining in-situ and remote diagnostics with numerical models.

1. Introduction

Plasma liquid interaction is relevant for a broad variety of applications, such as in plasma medicine for wound healing and cancer therapy, in agriculture for nitrogen fixation and pathogen inactivation, in environmental applications such as CO₂ reforming, and for chemical synthesis (see e.g. the recently published Special Issue on plasma-liquid interaction [1]).

With a growing range of applications, a detailed understanding of the underlying processes of plasma-liquid interaction – especially at the plasma-liquid interface – is more important than ever. Only, in most cases it is near impossible to study the processes directly at the interface.

This work presents strategies and limitations of studying plasma-liquid interaction and the involved chemistry by combining remote measurements of gas and liquid phase chemistry in combination with locally resolved chemical models.

2. Methods

Plasma liquid interaction is studied through gas phase analysis by absorption spectroscopy on collected remote gas, as well as by laser induced fluorescence spectroscopy in the plasma region combined with liquid analysis through colorimetry.

Investigations will be shown on an argon plasma jet at 1 MHz excitation frequency [2], as well as on a novel plasma-microfluidic platform that studies plasma liquid interaction in a multiphase flow [3].

3. Results and Discussion

Figure 1 shows results of a quasi 2D gas phase model of the plasma effluent chemistry, using a stacked plug-flow model that combines global modeling for slices of gas fluxes within the square cross sectioned plasma- and effluent-region with 2D-fluid simulation using COMSOL which determines flow fields, temperature distribution and water evaporation from a liquid interface. The gas phase chemistry is linked to a 2D-model of the liquid chemistry using a reduced reaction set. Model results are correlated to measurements of the hydrogen peroxide concentration measured downstream in collected liquid samples [4].

In the jet studies, it is shown that the liquid interface influences how reactive species are generated in the gas phase [5]. Humidity originating from the evaporated water influences, e.g., the generation of NO derived species.

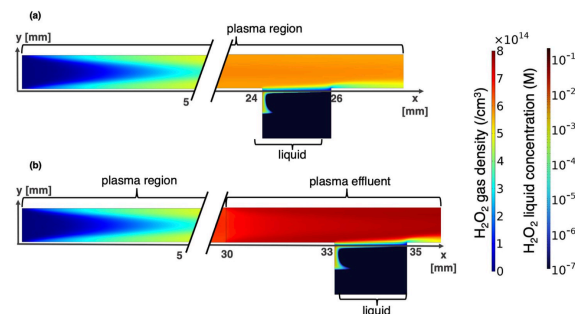


Fig. 1. Hybrid global and 2D-model linked to remote liquid measurements of H₂O₂ in a plasma microfluidic chip (reproduced from [5] with permission). Upper channel shows the plasma and effluent region of a confined COST jet while the lower box (mostly black color) shows a liquid which is placed under the plasma region (a) or the effluent (b).

4. Conclusion

Our studies show that remote measurements of gas and liquid composition in combination with numerical modeling can be used to identify fundamental processes at the liquid interface. While the method has strong limitations which arise from the time scales of the involved solvation and reaction rates and from the long-lived species detection methods' blindness to highly reactive and short-lived species, it allows to gain insight into the dominant plasma-liquid interaction processes.

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